HISTORICAL SUMMARY OF AIDS TO NAVIGATION ANALYSES: ANNOTATED BIBLIOGRAPHY

Final Report
Volume II

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HISTORICAL SUMMARY OF AIDS TO NAVIGATION ANALYSES: ANNOTATED BIBLIOGRAPHY

Abstract

This volume contains a detailed description of the various studies, analyses, and papers that were identified as part of the historical summary of aids to navigation analyses. The studies include 137 studies that have been reviewed in detail and for which an annotated bibliography has been prepared. Another 31 relevant studies have been identified that are part of the analysis in Volume 1. A total of 59 studies conducted by the Coast Guard Research and Development Center that focus on aid technology, buoy moorings, and hardware are summarized and categorized. A detailed categorization of the 137 reviewed studies is included. In total, this document contains an impressive summary of many years of detailed analysis that has been undertaken by the Short Range Aids to Navigation program and the Radionavigation Aids program to improve the level of service to the mariner and reduce the cost to the taxpayer for providing that level of service.

HISTORICAL SUMMARY OF AIDS TO NAVIGATION ANALYSES: ANNOTATED BIBLIOGRAPHY

1.0 INTRODUCTION

The Coast Guard is continually attempting to identify ways to improve the level of services offered to mariners and reduce the costs of doing so. The Short Range Aids to Navigation (SRA) program and the Radionavigation Aids (RA) program have made major efforts to achieve that continuous improvement. There have been numerous studies over the years that have addressed buoy technology, hardware and moorings. The resulting improvements have revolutionized the servicing requirements and subsequently changed the frequency of servicing from once every three months to once every two years. Those changes have led to reduced levels of servicing resources and associated costs. Even so, aids to navigation programs represent nearly 25% of the Coast Guard's operating budget. At the same time, more accurate and reliable electronic navigation capabilities are being developed and there is the possibility of moving from "*iron to silicon*" as a primary means of navigation.

As the challenge to increase services and reduce costs continues, it is valuable to review past efforts and identify whether there are important insights that have been observed in the past but overlooked and never implemented, and whether any of the analytical approaches that have been used in the past remain valid tools for future analyses. The purpose of this study is to look at the rich history of studies and analyses that have been completed over the years in support of the aids to navigation programs. Specific tasks include reviewing past analyses, conducting a technology survey, and examining cost analyses. Specifically, the statement of work required a review of all previous SRA/RA studies conducted by the Coast Guard from 1970 to the present. The technology survey task required an identification of the technologies in use at the time of the various studies and an assessment of what technologies are candidates for implementation in the future. A separate analysis of costing of program activities was envisioned in the task structure, but initial attempts by the Research and Development Center to develop such a cost structure was met with some resistance at headquarters administrative levels. Therefore, the cost segment of this historical summary includes an assessment of how costs were developed in various studies and to what extent cost was an explicit consideration.

Although the statement of work limited the review to studies conducted by the Coast Guard, there are a number of studies conducted by other agencies that are relevant and have been included. A total of 227 studies involving various aspects of the SRA program and portions of the RA program in the Harbor and Harbor Entrance domain have been identified. Of those, 137 studies have been reviewed in detail, 59 studies conducted by the Coast Guard Research and Development Center that have focused on aid technology, buoy hardware and moorings have been identified, and another 31 relevant studies have been identified through secondary references. The result represents a very substantial history of research and analysis supporting the aids to navigation programs.

The primary purpose of this volume of the final report is to provide the detailed documentation on these studies. Volume I of the final report discusses the relationships among the studies and their progression and contribution to the programs. The major contribution of this volume is a annotated bibliography for the 137 studies, analyses, and papers that were reviewed as a part of this effort. In addition to the review and annotated bibliography, all of the studies were categorized to indicate the area of primary and secondary focus. That categorization provided the basis for the discussion in Volume I. The reference listing for the annotated bibliography is included in Appendix A, and the annotated bibliography for these references is included in Appendix B. The 31 additional relevant studies (not reviewed) are included in the list of references in this volume. The 59 Coast Guard Research and Development Center studies are summarized and categorized in a later section of this report.

2.0 CLASSIFICATION OF REVIEWED AIDS TO NAVIGATION ANALYSES

In order to develop a chronological perspective of the historical development of the analyses in the annotated bibliography, they have been arranged in chronological order by year of publication. The index number is of the form YY-L-# where YY is the year of publication, L is the first letter of the first author's last name, and # is the sequential number appearing under that year and letter. The listing by index number is included in Appendix A. The alphabetical list of references is this volume includes the index number in brackets for cross reference purposes.

There are many possible means of classifying the various studies. Using the following categories, each study was identified with one **P**rimary classification and as many Secondary classifications as seemed appropriate. The following categories were used:

- *Advanced Technology (DGPS, ECDIS, ARPA, etc.)*--this includes most of the electronic means of navigation including vessel bridge electronics.

- *Aid Positioning*--this involves both manual and electronic means of positioning aids.

- *Aid System Performance Measures*--this category includes studies that focused on how well an aid system worked and attempts to measure that outcome.

- *ATON Policies*--this broad category generally includes issues like discrepancy response and servicing interval policies.

- *Buoy/Beacon Design, Hardware and Moorings*--this includes a number of major studies as well as some technical studies conducted by the Research and Development Center.

- *Buoy Tender Technology*--this includes studies that examined alternative hulls as well as operating characteristics that affect the development of replacement vessels.

- *Customer Identification/Requirements*--this includes studies that addressed particular customer needs and information required for safe navigation.

- *Human Factors*--this includes studies that have a significant involvement with the role of the human in aids to navigation, including information processing and use of navigation aiding devices.

- *Information Requirements/Systems*--this includes broad information needs for the operation of the programs.

- *Maintenance and Logistics*--this primarily involves support facilities and maintenance policy issues.

- *Modeling and Analysis*--this includes studies that have used a significant amount of model development and analytical approaches to represent and evaluate aid system elements.

- *Navigability, Safety, Risk*--this includes various analyses that addressed safety and risk from a navigability perspective (generally not explicitly involving the use of aids) that would affect the design of the waterway. Broad systems risk analyses are included here.

- *Operating Costs*--this includes an explicit consideration of the cost of only the component being examined.

- *Personnel Requirements*--this includes issues involving the assignment and training of personnel qualified for aids to navigation work.

- *Radionavigation Aids*--this includes those electronic systems that were intended to provide general navigation information as well as the use of those systems.

- *Servicing Mix*--this includes a myriad of studies and analyses that address the combinations of servicing resources needed to deploy and maintain the aids to navigation systems.

- *Systems Cost Issues*--this includes a consideration of a systems cost, and may incorporate the subsystem or component/alternative cost.

- *Vessel Positioning*--this includes studies that focused on enhancing the ability of a vessel to determine its position more accurately and reliably.

- *Waterway Design (Aid Location etc.)*--this is another broad category that includes those studies and analyses that attempt to shed light on what factors are important in designing a waterway, particularly with respect to what aid related factors are important.

Using these categories, the studies, analyses, and papers in Appendix B have been classified. A separate classification table is included with each annotated entry. The classifications for all 137 reviewed aids to navigation analyses are summarized below in Table 1. The table uses the index number for each reviewed analysis. Appendix A provides the easiest cross reference to the title.

Table 1: Classification Summary of Reviewed ATON Analyses

	CLASSIFICATION																		
STUDY	**Advanced Technology (DGPS, ECDIS, ARPA, etc.)**	**Aid Positioning**	**Aid System Performance Measures**	**ATON Policies**	**Buoy/Beacon Design, Hardware and Moorings**	**Buoy Tender Technology**	**Customer Identification/Requirements**	**Human Factors**	**Information Requirements/Systems**	**Maintenance and Logistics**	**Modeling and Analysis**	**Navigability, Safety, Risk**	**Operating Costs**	**Personnel Requirements**	**Radionavigation Aids**	**Servicing Mix**	**Systems Cost Issues**	**Vessel Positioning**	**Waterway Design (Aid Location etc.)**
67-U-1				S									S			**P**			
69-G-1							S						S			**P**			
69-G-2			S				S												**P**
70-B-1					**P**					S			S	S		S			
70-B-2				S	S					S			S	S		S			**P**
70-B-3				S	S				S	S			S	S		**P**			
71-C-1			**P**																S
71-C-2														**P**					
72-B-1								S				S							**P**
72-M-1	**P**											S							
72-U-1						S										**P**	S		
74-B-1								S				S							**P**
76-A-1		**P**																	
76-U-1																**P**	S		
77-A-1		S	S	**P**			S	S	S	S	S	S	S	S		S	S		S
77-E-1					**P**														
77-G-1		**P**																	
77-G-2		**P**																	
78-A-1		S	S	**P**			S	S			S	S					S		S
78-B-1		**P**																	
78-C-1			S	S			S	S			S	S				S	S		**P**
78-C-2		**P**																	
78-G-1					**P**														
79-B-1			S	S				S				S							**P**
79-D-1					**P**							S							
79-L-1											S					**P**			
80-C-1	S		S					S		S					**P**				S
80-M-1	**P**											S							
81-C-1	**P**							S				S							
81-C-2	S			S				S				S			**P**				
81-C-3	S			S				S				S			**P**				
81-C-4	S		S	S				S				S							**P**

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CLASSIFICATION																				
STUDY	**Advanced Technology (DGPS, ECDIS, ARPA, etc.)**	**Aid Positioning**	**Aid System Performance Measures**	**ATON Policies**	**Buoy/Beacon Design, Hardware and Moorings**	**Buoy Tender Technology**	**Customer Identification/Requirements**	**Human Factors**	**Information Requirements/Systems**	**Maintenance and Logistics**	**Modeling and Analysis**	**Navigability, Safety, Risk**	**Operating Costs**	**Personnel Requirements**	**Radionavigation Aids**	**Servicing Mix**	**Systems Cost Issues**	**Vessel Positioning**	**Waterway Design (Aid Location etc.)**
82-D-1	S		S									S							**P**
83-M-1			S	S				S				S							**P**
83-M-2			S	S				S				S							**P**
83-R-1								S			S	**P**							S
83-S-1	**P**							S				S							
83-S-2			S	S				S				S							**P**
83-U-1				**P**			S					S	S	S		S			
84-M-1			S	S				S				S							**P**
84-T-1					**P**							S							
85-H-1	S										S	**P**							
85-K-1	S										S	**P**							
85-M-1			S	S			S	S				S							**P**
85-M-2			S	S				S				S							**P**
85-O-1								S				**P**							S
85-S-1			S	S				S				S							**P**
86-G-1			**P**								S	S							S
86-W-1					**P**							S							
87-C-1											S					**P**			
87-U-1	S				**P**	S										S			
87-U-2	S				**P**	S										S			
87-U-3				S									S			**P**			
87-U-4				**P**								S		S		S			
87-W-1				S												**P**			
87-Y-1				S	S	**P**													
88-B-1			S	S				S				S							**P**
88-B-2			S	S				S				S							**P**
88-C-1											S					**P**			
88-K-1											S					**P**			
88-P-1															**P**			S	
88-U-1						**P**										S			
89-G-1	**P**			S				S				S			S				
89-T-1												S	**P**			S			

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STUDY	**Advanced Technology (DGPS, ECDIS, ARPA, etc.)**	**Aid Positioning**	**Aid System Performance Measures**	**ATON Policies**	**Buoy/Beacon Design, Hardware and Moorings**	**Buoy Tender Technology**	**Customer Identification/Requirements**	**Human Factors**	**Information Requirements/Systems**	**Maintenance and Logistics**	**Modeling and Analysis**	**Navigability, Safety, Risk**	**Operating Costs**	**Personnel Requirements**	**Radionavigation Aids**	**Servicing Mix**	**Systems Cost Issues**	**Vessel Positioning**	**Waterway Design (Aid Location etc.)**
90-D-1	S				**P**														
90-K-1							D				S	S				**P**			
90-K-2	S	**P**													S				
90-L-1					**P**							S							
90-M-1	S							S				S			**P**				
90-R-1					S	**P**			S								S		
90-S-1			S	S				S				S							**P**
90-T-1												S	**P**			S			
90-W-1					**P**							S							
91-D-1					**P**								S				S		
91-D-2											S					**P**			
91-M-1			S	S							S	S							**P**
91-S-1	S	S										S			**P**			S	
91-V-1	S											**P**							
92-B-1				S							S					**P**			
92-B-2				S							S					**P**			
92-B-3				S							S					**P**			
92-C-1											S					**P**			
92-G-1	**P**										S	S							
92-I-1				S							S					**P**			
92-M-1	**P**							S	S		S	S							
92-S-1			S	S				S				S							**P**
92-S-2	S							S	S			S			**P**				
92-S-3	**P**											S		S	S				
92-U-1				S												**P**			
93-A-1	**P**								S			S			S				
93-B-1				S							S		S			**P**			
93-B-2				**P**			S					S	S		S	S			
93-G-1	**P**							S	S			S		S					
93-L-1	S							S	S			**P**		S	S				
93-M-1				S	S				S	**P**									
93-P-1	**P**			S			S		S			S			S				

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93-S-1	S	**P**		S								S			S			S	
94-B-1											S		S			**P**	S		
94-F-1				**P**															
94-F-2																	**P**		
94-M-1	**P**	S										S						S	
94-S-1	**P**						S	S	S			S							
94-S-2	**P**							S				S			S				
94-S-3	S	**P**													S			S	
94-U-1				S						**P**									
94-U-2				S					S				S			**P**			
95-B-1	S								S										**P**
95-B-2				S					S		S	S				**P**			
95-C-1												**P**							S
95-E-1	**P**											S			S				
95-G-1	**P**							S				S							
95-G-2	**P**							S				S							
95-L-1	**P**										S	S			S				
95-L-2	**P**								S						S				
95-M-1										**P**			S				S		
95-M-2							**P**	S	S		S	S					S		
95-M-3	S						S	S	S		S	S			S				**P**
95-S-1	**P**							S				S							
95-S-2	S	**P**									S				S				
95-U-1	S		S	S							S	S			S				**P**
95-W-1			S								S	S							**P**
96-B-1									**P**		S					S			
96-G-1	**P**							S	S			S							
96-G-2	**P**							S				S		S	S				
96-H-1		S					S		**P**			S			S				S
96-N-1							S	S	S		S	**P**					S		S
96-S-1	**P**											S			S			S	
96-S-2	**P**	S													S			S	

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STUDY	**Advanced Technology (DGPS, ECDIS, ARPA, etc.)**	**Aid Positioning**	**Aid System Performance Measures**	**ATON Policies**	**Buoy/Beacon Design, Hardware and Moorings**	**Buoy Tender Technology**	**Customer Identification/Requirements**	**Human Factors**	**Information Requirements/Systems**	**Maintenance and Logistics**	**Modeling and Analysis**	**Navigability, Safety, Risk**	**Operating Costs**	**Personnel Requirements**	**Radionavigation Aids**	**Servicing Mix**	**Systems Cost Issues**	**Vessel Positioning**	**Waterway Design (Aid Location etc.)**
96-V-1			S						S		S	S							**P**
96-V-2							**P**		S			S							S
97-C-1	**P**						S		S		S	S			S			S	
97-G-1	**P**							S	S			S							
97-S-1	**P**								S			S			S				
97-S-2	**P**														S			S	
97-U-1		S					S		S			S			**P**			S	
97-U-2	S						S					S	**P**	S		S	S		
98-R-1	**P**							S							S			S	

3.0 RESEARCH AND DEVELOPMENT CENTER AID TECHNOLOGY STUDIES

The 59 studies conducted by the Coast Guard Research and Development Center that focus on aid technology, buoy hardware, and moorings are summarized in Table 2. In addition, each study is categorized as follows:

- Aid Use--this includes optical and other considerations for use of visual aids.
- Power--this includes various studies that examined alternative power sources for aids.
- Mooring--this includes various systems that affect the moorings of buoys.
- Design--this includes studies that examined alternative shapes and materials for aids.

These studies were not reviewed because they were perceived to have value as historical documents, but would have little effect on future aid system designs. Current issues are included in the reviewed studies.

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